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ARCADE

Aligning Research & Innovation for Connected and Automated Driving in Europe

D3.7: Society thematic areas: challenges and scenario

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Contents

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Executive summary

ARCADE is to coordinate consensus-building across stakeholders for sound and harmonised deployment of Connected, Cooperative and Automated Driving (CAD) in Europe and beyond. The Thematic Areas (WP3) work on content creation leading to consensus-based positions, needs and scenarios. According the Project Plan, this report is addressing the corresponding scenarios and challenges regarding the layer of “Users & Society”, in parallel with the reports on “Systems & Services” as well as “Technologies & Vehicles”.

Derived from the predecessor project CARTRE, four scenarios were defined (0, A, B, C). Scenario 0 describes comprehensively short-term issues. Scenario A “Disruption through market-driven services” and B “Authority driven with focus on collective transport” are deeply looking into the development of shared mobility services and public transportation as well as policies and the role of transport authorities. Scenario C is comprehensively looking into privately owned automated vehicles.

The thematic areas within Users & Society are defined in ARCADE to be:

– Policy and regulatory needs
– Socio-economic assessment and sustainability:
– Safety validation and roadworthiness testing
– User awareness, societal acceptance and ethics.

After having analyzed challenges and enablers in the different scenarios, key actions per area have been identified:

Policy and Regulatory needs:

- Allow a successful transition of responsibility from the user to the automated system (robot, manufacturer, supplier, etc.).
- Develop regulation regarding collection, use, re-use, of data and compliance to GDPR.
- Develop models on co-habitation of private shared and public mobility.
- Focus technical regulation on public transportation rather than private passenger cars.

Socio-economic Assessment and Sustainability:

- Organise both large-scale pilots (low level TRL) and FOTs (high level TRL) to assess the implications of the new technology and related services in different environments.
- Develop commonly agreed methodologies and tools.

Safety Validation and Roadworthiness Testing:

- Develop a common EU testing and validation methodology.
- Study expected life-time costs of Connected and Automated Vehicles (CAVs) and related infrastructure up keeping.

User awareness, societal acceptance and Ethics:

- Roles and liabilities over automated mobility should be clarified and consolidated.
- Investigate how the role of operators and professional drivers will change with higher levels of vehicle automation by conducting tests.

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This deliverable together with the deliverables on “technologies & vehicles” and “system & services” is the baseline of the further ARCADE developments in year 2. The methodology of the project will provide the opportunity to iterate the discussions on all of the subjects treated in the present document as well as any new subjects that might evolve from future discussion.

The next steps, plan for ARCADE WP3 year 2, will focus on additional scenarios, approaches, impacts and proposed steps; 2 joint stakeholder network workshops; thematic input for the EUCAD symposium at TRA in April 2020 in Helsinki and consolidation of the year 2 input to the thematic areas and provide input to the knowledge base (WP4)

These steps will lead to three updated reports at the level of Society, Systems and Services and Technology and Vehicles (September 2020).

1. Introduction

1.1. About ARCADE

ARCADE is an EC-funded Action that supports the commitment of the European Commission, European Member States and the industry (cf. the Amsterdam Declaration, GEAR 2030 final report, EC Communication on automated mobility[1], High-Level Structural Dialogue on connected and automated driving) to develop a common approach to development, testing, and validation of Cooperative and Automated Driving (CAD) in Europe and beyond.

The mission of ARCADE is to coordinate consensus-building across CAD stakeholders to develop this common approach. ARCADE involves 70 consortium and associated partners (to date) from 22 countries within and outside EU, who form the backbone of the Joint CAD Network of experts and stakeholders. This Network is composed of organisations from the public, industry and research sectors, stakeholder associations or individual experts, and was first established by the CARTRE Support Action (2016-2018).

In an annual cycle, ARCADE positions the Joint CAD Network (WP2) and Thematic Areas (WP3) centrally. The Network brings together the CAD stakeholder community at national, European and international levels while thematic areas work on content creation leading to consensus-based positions, needs and scenarios. The Knowledge Base (WP4) consolidates the CAD knowhow baseline and serves as a one-stop shop overview of CAD-related information. These main activities are depicted in **Error! Reference source not found.**.

The main expected results of ARCADE are:

- Knowledge Base including CAD European, national and international R&I projects, roadmaps, regulations, standards, testing methodologies, etc.;
- Better understanding of challenges, enablers and research gaps on 12 thematic areas related to CAD, and recommendations for next steps and actions;
- Exchanges and harmonisation of R&I approaches across EU, US, Japan and other countries outside Europe;
- Awareness raising and promotion of national, European and international CAD R&I activities and results.

ARCADE capitalizes on CARTRE legacy, including tools developed by the project such as the https://connectedautomateddriving.eu website, the work done in the thematic areas and of course, the Joint Stakeholder Network, which ARCADE will leverage and further grow.

[1] COM(2018) 283

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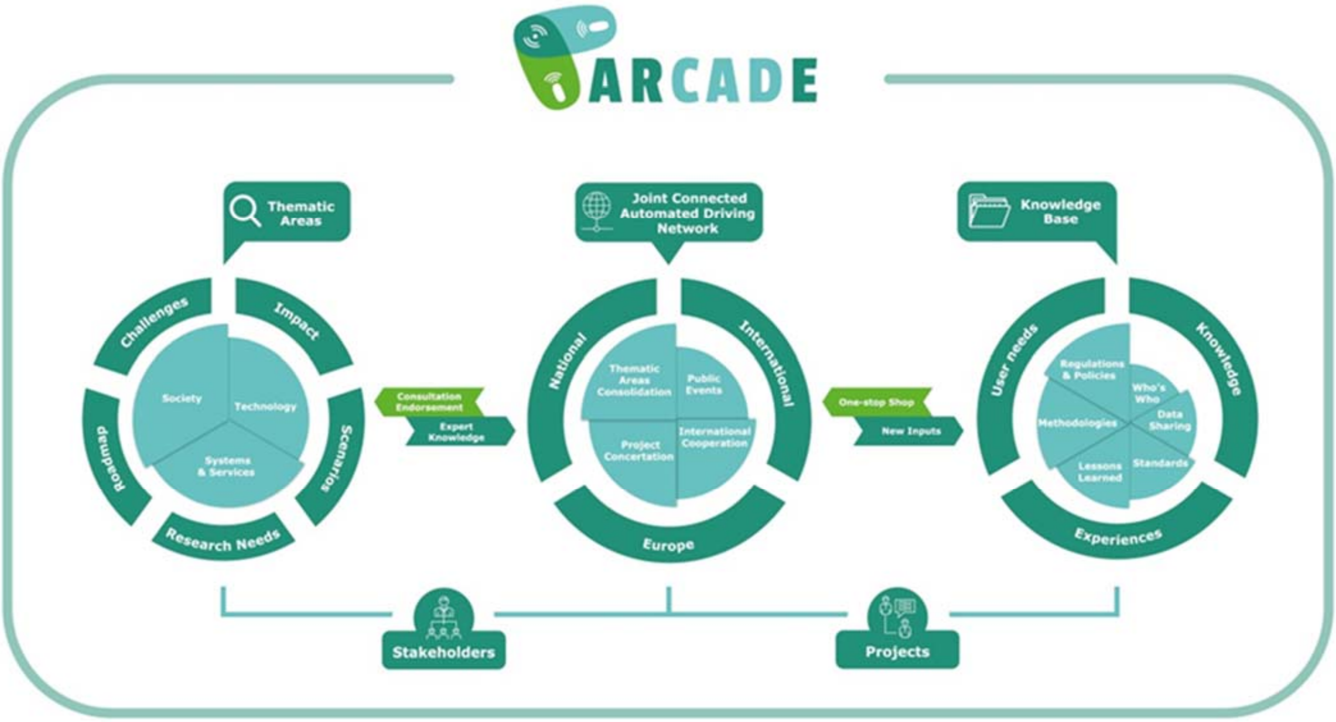

Figure 1: ARCADE main activities

1.2. Purpose of the document

Work Package 3 deals with the thematic areas and has the goal to deliver the research content. At the end of year 1, ARCADE provides three reports in parallel, one by each task combining work from several thematic areas. The structure of all 3 reports is similar. The focus for year 1 is for all 3 tasks on challenges and scenarios: what is blocking fast and good introduction of CAD or may create a negative impact? What should be solved to create a positive impact? In what diverse ways could CAD evolve in the period up to 2035? Year 1 Deliverables are the first step with scenarios as a means to better reach the full bandwidth of research. It does not mean that the selected scenarios are a prognosis of the reality in the future, they only show the possibilities. This first version will be enhanced during Year 2 and 3 by additional aspects and updates to the current content.

This document addresses these challenges and scenarios in the layer of “Users & Society”.

1.3.Intended audience

The document is addressed to the European Commission to give a full picture on the research themes, their challenges and corresponding actions. It is also addressed to the stakeholder community for detailed understanding of research needs, other stakeholders involved and challenges on the road to deployment.

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2. Description of scenarios

2.1. The CARTRE scenarios

The preceding project CARTRE[2] determined four alternative scenarios for making expert assessment of the socio-economic impacts of automated driving [reported in Rämä et al. 2018 on which this chapter is based]. Scenarios were plausible descriptions of the future; they can be seen as stories of different alternatives for what could happen and for what the transport system could look like. All the scenarios focused on transport of people (and less on freight). The CARTRE expert assessment work covered eight impact areas and multiple KPIs in all of them.

The CARTRE scenarios were not mutually exclusive but they helped to look at different impacts of CAD from different perspectives.

The short-term scenario (scenario 1) refers to the near future (not 'tomorrow'), up to around 2025. The long-term scenarios (2, 3 and 4) are still fairly close timewise – somewhere around 2035. Current technology paths cannot be extrapolated much further without creating large uncertainty. On the other hand, since the lifecycle of development and use of vehicles is quite long, it can be expected that vehicles that are developed today are partially still on the road in 2035. The average age is 11.1 years for cars and 12 years for heavy commercial vehicles[2] which can even reach to 15 years[3]. Annually, about 20% of cars is replaced by a new one[4].

In the short-term scenario the focus was on gradual extrapolation of automated services with no radical changes to the current. The same automated vehicle technologies and their maturity was assumed in all the long-term scenarios. In addition to the time aspect and maturity of technology, the development of shared mobility services and the locus of control (role of public authorities) were identified as the main differentiating factors between the scenarios. Specifically, the first of the long-term scenarios described a transport system in which automation emerges parallel to shared mobility, and the fleets of automated vehicles are market operated. The second long-term scenario pictured a future in which shared automated transportation is authority driven. In the third long-term scenario, automated vehicles are mostly privately owned and shared mobility has not succeeded. A summary of the scenarios and their main differences is illustrated in Table 1.

Table 1 Summary of assessment scenarios (CARTRE)

	SHORT-TERM SCENARIO (~2025)	**LONG-TERM SCENARIOS (~2035)**		
	Scenario 1 *Gradual extrapolation of automated services*	**Scenario 2** *Market-operated fleets of shared automated vehicles*	**Scenario 3** *Authority-driven shared automated transportation*	**Scenario 4** *Proliferation of private automated vehicles*
Automated vehicle technology	Gradual introduction of automated functions	Mature SAE L4 automated vehicles, penetration >50% in mixed traffic		

[2] Rämä, P., Kuisma, S. (2018). Societal impacts of automated driving. CARTRE Deliverable D5.3

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Use of shared mobility services	High interest, early adopters use	High	High	Low
Locus of control	Cautious but enthusiastic public support for automated vehicles & mobility services	Private	Authority-driven, public-private collaboration	Private

For the scenario-based assessment of the socio-economic impacts CARTRE suggested that in the short term, the impacts of automated driving would be minor or moderate. In the assessment of the long-term scenarios, the two scenarios that included shared mobility showed the more benefits from automated driving compared to the scenario with private automated vehicles.

2.2. Selection of scenarios for ARCADE

In ARCADE, we use scenarios to explore the implications for the various thematic areas in the sense of challenges, enablers and actions to be taken. Therefore, a selection of the CARTE scenarios was made that would suit the exploration best. The selected scenarios are meant to explore the variety of developments. They are not a recommended or desired scenario, just possible scenarios. As scenario 1 was used for the short term within the previous project, and time has progressed, the team agreed to use it with less priority with one comprehensive chapter and named scenario 0. With regards to scenario 4: after many experts´ dialogues, it was found that with evolving technology the views on it have changed. It states that owning AV is affordable for most people, as a base thought. When researching scientific publications on AV sensors and computers, it is common sense that a full 360° coverage of all three sensor principles (Camera, Radar and Lidar) is needed for Level 4 with a corresponding on-board supercomputer for real-time raw data fusion. This means that cost per vehicle will stay extremely high for a long period of time. That is why in this deliverable it is assumed that scenario 4 is evaluated to be very optimistic. Furthermore, the working assumption is that the role and focus of the authorities is too narrow and not any more realistic in scenario 4. That is why this scenario is only looked at in one comprehensive chapter and named scenario C.

The remaining two scenarios are named scenario A and B and described in more detail in this report. As Level 3 Highway Automation is expected to be rolled out (as announced by many OEMs) in the first half of the 2020s and according to the ERTRAC Roadmap, this deliverable focuses on Level 4. The same automated vehicle technologies and their maturity is assumed in both scenarios. In addition to the time aspect and maturity of technology, the development of shared mobility services, the availability of public transportation and the locus of control (which actor controls the development most) were identified as three main differentiating factors between the scenarios (Brenden & al 2017, Milakis & al 2017, POLIS 2018). The differentiation of scenarios is for showing the possible range of the consequences of how technology will be applied to society and how systems and services are controlled. For scenario A the focus is on vehicle sharing and ride hailing for persons and goods on a more privately and individually organized system. For scenario B, the focus is on ride sharing strongly linked with an overall traffic management and public transport.

Future AD technologies are going to be built on the existing partial automation and related experience. In long-term SAE L4, functions in use include highway autopilot, urban and suburban pilot, and automated shuttles and buses in mixed traffic. The freight vehicles path includes SAE L4 HAVs (Highly Automated Vehicles) on dedicated and open roads and highway pilot platooning. It is also assumed that light goods vehicles (vans) for deliveries and services have automated L4 functionalities. The occurrence of automation differs, however, depending on the area, ODD of functions, willingness to use, adoption rates, etc. In these scenarios, we assume that SAE L4 functions are broadly available and mostly mature. Traffic will have mixed levels of automation. In addition, shared ownership and high technology solutions for vehicles may speed up the rate of fleet renewal.

2.3. Scenario 0: Short term Gradual extrapolation of automated services

Following the gradual launch of new automated functions, new cars have at least optional SAE L2 automation functions such as traffic jam assist, lane keeping assist and parking assist in addition to the SAE L1 ACC and Stop & Go assist. For freight vehicles, cooperative-ACC truck platooning is commonplace. SAE L2 AD functions for cars and SAE L3 functions were launched some time ago and are now spreading out.

This implies for Users and Society thematic areas:

Scenario 0: Gradual extrapolation of automated services (2025)

This scenario is the most short-term scenario. The focus is on gradual extrapolation of automated services with no radical changes to the current situation. In CARTRE this was described as:

Following the gradual launch of new automated functions, new cars have at least optional SAE L2 automation functions such as traffic jam assist, lane keeping assist and parking assist in addition to the SAE L1 ACC and Stop & Go assist. For freight vehicles, cooperative-ACC truck platooning is commonplace. SAE L2 AD functions for cars and SAE L3 functions for trucks were launched some time ago and are now widespread. Overall, there are more SAE L3 functions for freight than for cars: traffic jam chauffeur and highway chauffeur are expected to be in general use in trucks already in the short term (ERTRAC 2017, CARTRE D5.1 2017).

For cars, SAE L3 level functions have been introduced including traffic jam chauffeur, highway chauffeur and automated urban bus chauffeur (ERTRAC 2017, CARTRE D5.1 2017), but the system penetration is quite low (less than 20% at a rough estimate). In urban transport, bus assist (L2) and bus chauffeur (L3) have been launched and there are SAE L4 buses and shuttles on dedicated roads.

It is assumed in this scenario that new cars are equipped with cooperative systems to enable connectivity of vehicles and C-ITS. This means that more information about surrounding circumstances, incidents and traffic are conveyed to the drivers; introduction of eCall and CACC truck platooning (providing information on traffic downstream) are examples. However, as system penetrations are still small, automated functions cannot be built on the assumption of connectivity. In addition, we assume that the impacts of informative C-ITS services (Malone & al 2014) are smaller than those of interfering functionalities.

It is assumed in this scenario that user interfaces have been developed in pilots and field tests. Users are quite aware of the function properties, and the functions implemented are fairly widespread.

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In the following paragraphs, the challenges and enablers with priority will be discussed.

Regulations and policies considering SAE L3 functions will be unclear and fragmented. Issues lie in the application of legislation in urban mixed traffic environments and cross-border. Several individual EU Member States will prove to be more advanced in supporting CAD with the necessary infrastructure and preliminary regulations.

Moreover, the socio-economic benefits of CAD are not clear considering the low penetration rate. The impact cannot be measured, only assessed through simulation. Driving on the highway and freight traffic are benefiting most from an increased presence of CAVs.

In terms of roadworthiness and safety validation, methodology will be broadly aligned and accepted by 2025. However, providing an efficient and reliable quantified safety validation is still a challenge. The performance of CAVs is starting to be monitored by roadside checks and in-car logging and assessment.

From a user awareness and acceptance perspective, there are unclear expectations of CAV behaviour, safety and liability which make other road users hesitant of accepting CAD. Media coverage of incidents needs to be balanced with public information and statistics on accidents prevented through CAD. Hands-on experience with driving a CAV can also help to take away hesitations. The high price of current ADAS option packages may slow down adoption.

2.4. Scenario A for 2035: Disruption through market-driven services

In the following, Scenario A is described regarding two aspects: the development of shared mobility services and public transportation as well as policies and the role of transport authorities.

2.4.1. Development of shared mobility services and public transportation

Shared mobility services have broken through and became mainstream. Shared mobility Services include ride sharing, vehicle sharing and ride hailing, possibly covering several mobility modes. They are reliable and convenient in most cases. Fleets of shared and automated vehicles are market operated. Operators are competing against each other for customers, and different levels of service are available. Premium subscribers gain access to better and faster services than basic subscribers. These privately-operated fleets of vehicles have partly replaced traditional public transportation, especially on short distance trips and in densely populated areas.

Shared mobility is mainly based on the provision of vehicles and services, giving less attention to multimodal travel and integration with public transport services are not really multimodal, as cooperation is not optimized, travel chains do not cover all modes well. New services and business models for public transportation are continuously being developed in parallel with private mobility services. An increase of driverless buses is reducing the costs of bus travel.

2.4.2. Policies and the role of transport authorities

Since market-operated fleets of shared and automated vehicles competes and complements traditional public transportation, road authorities aim to promote social equity by regulations and subsidies to ensure a minimum level of mobility services to all people. Transport authorities affect market-operated transportation through regulations and subsidies that clarify responsibility issues and encourage private operators towards lower emissions, increased

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road safety and intelligent use of urban space. Privately owned vehicles are not subject to a special policy.

2.5. Scenario B for 2035: Authority driven with focus on collective transport

In the following, Scenario B is described regarding two aspects: the development of shared mobility services and public transportation as well as policies and the role of transport authorities.

2.5.1. Development of shared mobility services and public transportation

In this scenario, there is a system of driverless vehicles providing demand-responsive public transportation for selected routes. There has been a proliferation of commercially explored automated public transportation systems (e.g. busses, shuttles, pods, delivery). The main private operators of public transportation have invested in creating these systems, which have been subsidized by the public sector. The main use of the systems is for access and egress of major public transport hubs and for lower-density areas. Most of the people have accepted and been used to sharing trips and vehicles. Travel chains are well functioning and intermodal.

2.5.2. Policies and the role of transport authorities

Shared and automated mobility is part of the integrated planning process, which is based on public-private collaboration. Transport authorities are proactive and, ensure social equity. They also keep strategic control of the transport network. Privately owned vehicles are being discouraged, both centrally and locally for example through road price charging and parking charges. Physical and digital infrastructure has been built in (part of) the strategic network.

2.6. Scenario C for 2035: Privately operated fleets and low governance

This scenario is focused on private ownership of a highly automated vehicles, similar to today's situation. The cost price of the vehicles will rise due to expensive sensor systems required for SAE L4 vehicles. In this scenario, people do not want to use shared automated vehicles together with strangers and without a driver present. Thus, sharing remains marginal, not many systems have broken the barrier to being commercially explored by private companies, and public companies are not adopting them. Authorities have not been able to get public acceptance to govern the use of private automated vehicles, especially in urban areas. Policies focus on reducing emissions, managing urban space effectively, and increasing the safety of automated vehicles.

This implies in comparison to Scenario A and B for Society related thematic areas:

Regulations and policies are present in several EU Member States that have SAE L4 and L5 vehicles on the road. These policies are not thoroughly applied in all EU Member States due to the diverse landscape across the EU with some countries not having the same level of presence of such vehicles as compared to others. The public authorities' role focuses on public health & safety, as expressed in minimum safety, road use and emission regulation. The further development of CAVs and urban and rural mobility is left to private initiatives.

The socioeconomic impact reflects the high price of SAE L4 vehicles, a sharp distinction between owners of CAVs and non-owners will arise. Public transportation may become a 'poor man's transport' only. Non-owners will keep driving conventional vehicles for a long time. Social inclusiveness struggles to advance given the unease by passengers to share automated vehicles.

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Regarding safety validation and roadworthiness testing, the minimal safety and safety assurance is covered by the public bodies and authorities. Further safety optimization is left to market forces. Private companies may use monitoring of vehicles for further comfort improvement and reduction of liability. Roadworthiness testing and safety validation face challenges related to the higher levels of automation. Authorities have not yet developed an efficient way to prevent cyberattacks and to safely validate OTA software updates.

Due to the divide between CAV owners and non-owners, social acceptance will be limited. The users are aware of which vehicles are automated and may behave differently. Even though users are confronted with affordable automated vehicles, user acceptance is not being stimulated enough by the authorities. This availability of technology is not fully appreciated by society and cannot draw any significant benefits. Considerable investments will need to be made to retrain drivers and operators in order for them to successfully supervise automated vehicles and take appropriate measures if necessary.

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3. Scenario detailing for the Society thematic areas

Scenarios A and B take into consideration the work that was carried out in ARCADE thus far with several stakeholder workshops. These stakeholder workshops aimed at identifying possible bottlenecks and challenges, and enablers related to different scenarios.

Successful deployment of CAD will depend on how rapidly and to what extent society will embrace technological change on the road. Currently, society's perception of CAD is unclear also due to the media focusing on accidents involving CAVs. It is the responsibility of the transport sector to gradually convince users and society as a whole that the deployment of CAVs will bring significant benefits. Public awareness activities demonstrating the functioning of new technology and the ability to generate new services will contribute to an increase in general acceptance and interest in making use of new opportunities.

In order to have a thorough understanding of the scenarios described above from a societal point of view, the following ARCADE thematic areas gave input to this deliverable:

- Policy and regulatory needs, European harmonisation policy
- Socio-economic assessment and sustainability
- Safety validation and roadworthiness testing
- User awareness, societal acceptance and ethics, driver training.

The input provided by each thematic area is combined with suggestions from other stakeholders during past workshops. The aim is to provide a comprehensive overview of how society will be impacted by fast-paced changes which are taking place in the sector.

One of ARCADE's main objectives is to further develop the work carried out in CARTRE relating to the thematic areas. In order to do so, a single approach was defined for WP3 and the three different thematic area groups: technology, systems and society related.

Important note for the understanding of the structure of this Deliverable:

Scenario A is used to describe all aspects of Society related thematic areas, represented by the above mentioned four thematic areas. In order to avoid doubling parts, Scenario B only highlights the difference to Scenario A. No significant difference between the scenarios was found with regards to relations of ongoing activities outside of ARCADE. Therefore, the activities are described in chapter 3.2.3 for both scenarios.

3.1. Scenario A: Disruptions through market driven services

The impact of market-driven services could allow the mobility ecosystem to further develop in terms of technological advances. Various stakeholders competing against one another might attract users by providing them with a wide selection of services. On the other hand, having no concrete regulation in place could lead to a fragmented and vulnerable environment in which users' rights are overlooked.

Scenario A predicts that there will be disruptions through market-driven services. For this reason, several bottlenecks and challenges were identified that touch upon the society-related thematic areas. Consequently, enablers corresponding to the bottlenecks and challenges are proposed and analysed.

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3.1.1. Bottlenecks and challenges

Policy and regulatory needs

Legislation can be a barrier for testing. For innovation, it is beneficial that some cities or regions already take the initiative to change their legislation to allow for experimentation – rather than waiting for a comprehensive national- or European-wide legislative framework. These separate initiatives however lead to fragmented and unclear rules which in turn make it more difficult for the industry to test across Europe. Initiatives are currently taking place at national level, among others, in France, Germany, The Netherlands, Spain, and the United Kingdom (Graeter, Rosenquist, Steiger, & Harrer, 2019, pp. 28-37).

It is likely that these new market-driven services create discrepancies in transportation regulations in different countries and that certain countries benefit from regulations that are pushing technologies more actively than others. Therefore, best practices should be encouraged in order to make seamless transportation affordable not only in advanced countries but also in countries where new mobility could be possible but obstructed by too much regulation. On the other hand, regulations must also primarily consider safety and take into account the latest demonstrations in safety validation of automated transport services.

Technology is increasingly based on high-performance sensors and data fusion, but even more on complex algorithms based on artificial intelligence and machine learning. This raises again the question regarding the responsibility of technology in making the automated system more autonomous. Regulation has to address this progressive transfer of responsibility. Moreover, shared, automated mobility will produce a significant amount of data that is collected, stored and analysed (and most likely re-used) which makes the issue of protection of data extremely important. More flexible or, at the same time, more complex and rigorous regulation is needed to protect personal data.

Current traffic rules may not always be interpreted in a correct manner by digital systems. Traffic rules vary by EU Member State and the system will need to be able to adapt to different rules when crossing into another country. At the same time, rules can be ambiguous or contradict each other, resulting in digital systems not following them correctly. Furthermore, there are unwritten rules that digital systems cannot adopt easily (e.g. many cross a continuous road marking in order to pass a stationary vehicle or a cyclist).

It is not clear at the moment which CAD technologies will emerge as successful, i.e. reliable, performant, sustainable, safe and affordable. There are still many open options. Successful technology will of course depend on technical feasibility but also on real-world demand for specific use cases, such as (shared) passenger car automated mobility, robot vehicle, ride-hailing, short distance shuttles, longer distance shuttles, on-demand automated transport, etc. Experiments are currently running all over Europe and outcomes of these experiments should show what the best cost-beneficial use cases are. Currently, it is still challenging to predict what they really will be at the end of the day. Therefore, it is also challenging to identify what the regulation for this technology should subsequently be. Ideally, regulation would be able to accommodate different solutions as long as they comply with certain societal criteria.

Socio-economic assessment and sustainability

The first set of European pilot projects on AD (SAE L3 and higher), conducting their tests under the H2020 framework around 2020, offer a view into technology advancements.

However, these first tests are limited in areas where automation can be operated and tested safely. Test subjects are rarely given free access to the vehicles due to the prototype nature of most of the vehicles. As a result, this sets clear limitations on studying long-term impacts and how automation impacts the daily life of test subjects. Instead, long-term impacts must be deducted and simulated using various methods, as first-hand proof does not exist yet.

As new AD functions continue to develop into products or close-to-market prototypes, wider user tests become possible. It is likely that these tests will first have to be conducted in specially selected and instrumented city districts or motorway environments, to provide required infrastructure support as well as to study cooperation between several automated vehicles.

A challenge in Scenario A, from a socio-economic impact viewpoint, is that the benefits in terms of improved mobility possibilities of these market-driven shared mobility services (that are based on automated vehicles) are only for those living in densely populated areas and with access to smart phone applications. If affordable mass transit is less used, the level of service quality for them is likely to decrease. There is a risk that using only subsidies and regulation for provision of the basic mobility for all may lead to (more) expensive transport system operation for the municipalities than in other alternatives – more expensive than they can afford, leading to worse quality for basic mass transit. Thus, in society, the mobility of some would improve but for others it would get worse, causing equity challenges.

An additional challenge is how to plan the land use in this kind of scenario to minimise the harm and to support creating equal mobility services, offering possibilities for all, and at the same time, enhance wellbeing and sustainability in all areas. In addition, there is a risk that these services in Scenario A will impact on active travel models such as walking and cycling.

Challenges like the ones described above are beyond possibilities to be studied in simple simulation models that are traditionally used to assess the socio-economic impacts. Thus, new evaluation methods need to be developed for the indirect long-term impacts. This includes research on users/consumers (acceptance, willingness to pay, travel behaviour, etc.) in addition to research on other fields/ thematic areas such as technology development, safety of solutions and transport network efficiency impacts.

Safety validation and roadworthiness testing

Safety validation and roadworthiness testing are concerned with the definition and standardisation of methodologies and tools in order to verify whether CAVs fulfil the safe performance of the implemented technologies. It is one of the building blocks to achieve the safe deployment of automated road transport on public roads. Likewise, it will be an important factor to establish people's trust in CAVs.

The following challenges must be addressed in order to create complete, reliable and evolving validation procedures:

There currently is a lack of a harmonised validation methodology based on a common state of the art and flexible enough to adapt to new technologies and realities (i.e. higher penetration of automation in the mixed environment) (see also Deliverable 3.1, chapter 3, Deployment).

CAVs need to be able to seamlessly function in a real-world environment. However, it is extremely challenging for a CAV to address risks associated to its surroundings especially due

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to the presence of Vulnerable Road Users (VRUs). The vehicle will need to anticipate unlikely circumstances.

Ensuring safe and reliable driving behaviour of CAVs requires significant efforts with regards to testing. Evolving from existing Advanced Driving Assistance Systems (ADAS) and SAE L2 systems to higher levels of automation by using different and combined testing means (virtual validation, test tracks, driving simulators and field tests) would be an efficient solution. It will be necessary to find a good balance between simulation and kilometres driven in real-life (proving ground and/or public roads) on the one hand and to deal with the remaining uncertainty in the actual safety and performance of the system. In the particular case of Virtual Testing, perception (trustworthy sensor models) is one of the main challenges for validation of CAD.

An additional aspect of CAV validation is human interaction and driver / user acceptance. The vehicle interaction with the driver or vehicle users, as well as with the rest of road users must be reflected in safety validation.

Over-the-air (OTA) software updates inside CAVs will play a decisive role in terms of road safety. The behaviour of CAVs may change before and after a software update. The vehicle's perception of risks around it could be altered and therefore jeopardise the safety of other road users. In light of this, emphasis will shift from one-off admission to continuous monitoring of robustness of the vehicle's driving behaviour (see also Deliverable 3.1, chapter 3, In-vehicle enablers).

Interaction between infrastructure and vehicles might be changed or improved i.e. with new communication standards or message sets that might have an impact on already deployed vehicles. As a result, new tests might be required to make sure legacy vehicles maintain their original safety performance.

Maintenance of CAD systems should be followed during the vehicle lifecycle and regular updates (over-the-air or through other means) have to be considered. The potential impact OTA updates might have during the vehicle lifecycle and re-certification schemes have to be defined. The Periodical Technical Inspection (PTI) procedure might also have to be reviewed in terms of periodicity and the tests carried out to check the correct functioning of the automation features (sensors, software) of the vehicle.

User awareness, societal acceptance and ethics, driver training

Given the prominence of automated, shared fleets operating in cities in Scenario A, user awareness of CAD should reach a level in which users are comfortable sharing the road with CAVs. Several aspects have to be considered in order to understand the importance of the perception of society. For automated, shared fleets to operate in a safe and efficient manner, legal and privacy issues should be clearly defined and understood by users. Users should be aware of the different options related to their personal data and how this data is used for advertisement or insurance purposes. Most importantly, users should be informed how liability rules apply to CAVs. Campaigns may need to be created to inform about who is liable (the AD system or the driver), so that users are ready when CAVs are coming on the market.

Automated transport changes mobility patterns, especially with respect to public transport. A large number of people prefer to not go from private car to public transport because they enjoy

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having control of their journey or do not want to get in the same vehicle with others, and automated road transport will take control from the users.

In addition, user awareness and societal acceptance heavily depends on the ethical decisions of CAVs. It is extremely challenging to develop Artificial Intelligence (AI) that will reduce accidents on the road without never being forced to make a decision that could ultimately be seen negatively by users. A further challenge is determining who sets the rules and in what detail related to the decisions made by a vehicle.

In 2035, drivers will still be needed (e.g. remote control centres) despite the existence of vast amounts of shared and automated vehicle fleets. For this reason, the driver should be informed about the vehicle's ADAS and how to interact in terms of Human-Machine Interface (HMI). Driver training would need to be adapted to technological changes and the new and ultimately different tasks the driver would need to perform inside the vehicle (see also Deliverable 3.1, chapter 3, Human Factors). These tasks could include monitoring vehicle AI or monitoring if the remote operator is safely executing the driving task.

As a result of higher levels of automation, jobs will be lost, and re-training will be costly for fleet operators. A particular burden for drivers is the need to obtain a new European Driving Licence which would include ADAS and the need to hold regular refresher courses should be foreseen for licence holders as the technology develops. This similarly will impact professional drivers since they will be required to take time off to undergo specific training. Governments should facilitate the transition and support Small and Medium Enterprises (SMEs) to enable them to compete against larger players in the transport ecosystem.

3.1.2. Enablers to speed up processes

Policy and regulatory needs

There currently are a few initiatives to determine best practices, guidelines or standards for the development of CAD applications including design, testing, verification, validation, transparent safety validation and evaluation of the societal impacts of CAD. These initiatives help a lot in understanding and raising consciousness about what is needed in terms of technical regulations, type approval, responsibilities and regulations in terms of traffic laws and transport operating laws (see for example "NHTSA Automated Driving Systems 2.0: A Vision for Safety, 2017" or "Safety First for Automated Driving, 2019). Furthermore, UNECE Working Party 29 created a new body in June 2018, "Working Party on Automated/Autonomous and Connected Vehicles (GRVA)". GRVA priorities include: Safety and security of vehicle automation and connectivity; Framework; Functional requirements; New assessments and test methods; Cyber security (and software updates); and Data Storage System for Automated Driving. One can therefore assume that the enabler 'technical regulatory policy harmonisation' has already started. Type approval should be normally derived from these technical advancements and high care is given by the EC that the technical regulation is the basis for common type approval European-wide.

For the purpose of developing and trialling new products, it is important not only to have enabling but also stable regulations to have clear boundaries to work within for product developers. As for non-technical regulations, harmonising traffic rules for automated transport all over Europe would be an enabler. Initiatives are emerging in some countries, such as Germany (Kessel & von Bodungen, 2018) and France (Development of Autonomous Vehicles: Strategic

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Orientation for Public Action, 2018) to amend the Traffic Code to allow some side tasks at the wheel in certain situations and to enhance driver training (responsible use of new technologies). Lessons should be learned from these initiatives and they can – where applicable – be used in other countries and/or Europe-wide.

As for public transportation, shared mobility and co-existence of multi-modal transport services, best practices deriving from current piloting or testing should pave the way for sustainable use cases. Political attention and will for the topic enable a beneficial environment for deploying technology that benefits society.

Socio-economic assessment and sustainability

Widespread use of common impact assessment methodologies, such as FESTA (FESTA Handbook, 2018), can harmonise evaluation efforts. Using a sound methodology also helps to build validity of evaluation results as the work then follows the phases of a scientific study. Methodologies can provide best practices and lessons learned, and they are not generally seen too binding, either. For small studies that have a strict timeline, methodologies provide helpful documents and checklists (see also Alkim et al., 2018). Evaluation communities can even share tools and data models.

There are ongoing efforts to provide guidance and tools specifically for evaluating automated driving. These include, updates to FESTA and e.g. Trilateral Impact Assessment Framework for Automation in Road Transportation (Innamaa et al., 2018), being developed in EU–US–Japan cooperation and aiming at harmonisation of certain aspects of evaluation to enable comparability and understanding of results. In addition, several data and simulation tools should become available in the next 3–5 years.

Regarding Scenario A specifically, the main enabler might be the general acceptance of shared mobility itself. In order to achieve the transport system like described in the Scenario, car-sharing and automated taxi services must reach a level of acceptance where the number of personally owned cars starts to drop. It would mean a drastic change considering the ever-rising car ownership numbers in the past decades. Such a change will likely not take place without strong demand management measures to discourage the use of non-shared automated vehicles.

In practice, the travel costs for the end user, per trip or per period, should clearly drop to be even comparable against costs of using a personally owned car. Quality of services (availability, reliability, cleaning, maintenance) should also be high in order to gain wide public acceptance and realise the scenario.

To limit the costs of infrastructure required by automated cars and vehicle fleets operated by private companies, standardisation should be sought for. It could also be possible to seek out new financial models for sharing costs of up-keeping required infrastructure. Societal savings through low accident rates might play a role in reaching such agreements.

Safety validation and roadworthiness testing

In order to solve some of the current challenges it is necessary to create a common testing and validation methodology which is accepted worldwide and enables multi-stakeholder cooperation.

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It is necessary to review the existing safety validation procedures that might be directly affected by higher levels of automation i.e. passenger passive safety in an automated vehicle, and potentially be outdated. This review should include all the already existing types of testing: compliance, commercial testing (i.e. Euro NCAP), and type approval/self-certification. An industry-wide international consent is required in order to have a common state of the art (see also Deliverable 3.1, chapter 3, Deployment).

Additionally, defining common validation frameworks that include the identification of key ODD-specific scenarios will lead to the description of a dynamic scenario database. Additional enablers include defining criteria to adequately combine testing by simulation, closed test tracks and on public roads (real life situation), and trustworthiness and defining the right Key Performance Indicators (KPIs) and safety metrics.

Validation methodologies must be built from consensus among different stakeholders. For instance, procedures for safety validation aligned with the vehicle development lifecycle will allow the optimal use of development time and resources. Whereas for SAE L2 system development, OEMs need two years for development. For SAE L3, there will be constant improvements and validation will not end at Start of Production (SOP). It is necessary to run safety processes in a proactive way and acquire regular check loops. In this sense, the validation methodology must be feasible and affordable by all manufacturers as well as other involved stakeholders (e.g. suppliers and AV technology companies) in terms of costs and timing and guarantees safety performance at user and societal level.

Information for the end user regarding vehicle characteristics is important. The way an AD function is developed has a great impact in its performance and safety. Consumer test programmes will provide information to the user about interaction with the vehicle, system performance in the areas of intended operation and relevant use cases, as well as limitations of the system and back-up behaviour in safety critical situations.

The alignment of validation methodologies and socio-economic impact assessment will optimise the information shared with current decision-making organisations. This will help defining a future strategy and provide a structured framework and methodical approach for thinking about and working with rapidly shifting technologies. Validation with a strong focus on HMI aspects and user interaction with the driver will allow meeting user expectations and achieving acceptance in order to build public trust in CAV.

New safety metrics will be obtained thanks to the elaboration of Safety Methods that take the entire traffic system as an additional aspect instead of just the vehicle (interaction between vehicle and other road users, human driver and infrastructure). Additional processes like Functional safety, Safety of the Intended Function, Cybersecurity will also be key to avoid safety hazards.

A procedure to manage the validation of vehicle updates will become necessary. If a vehicle hardware and/or software receives an update that modifies its functionalities, these changes and their impact on safety must be addressed. It is important to clearly understand when a new update should be considered different enough to start a new validation procedure or if new, different approaches able to deal with the update need to be developed.

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User awareness, societal acceptance and ethics, driver training

In Scenario A, citizens will see a multiplication of shared transport services develop, without the confidence that services guarantee minimum safeguards.

Public awareness is a key challenge to acceptance. User acceptance can only be achieved if information about automation developments is successfully communicated to the public. For this, efforts by different stakeholders, for instance through awareness campaigns should accompany the progressive deployment of automation functionalities. Also, hands-on experience and social discussion of automation will raise user awareness. However, current models for studying user acceptance of new technologies are not suitable for acceptance of road automation for example for liability and ethical issues.

When it is assumed that road users are fully aware of automated driving possibilities, one of the biggest challenges for automated driving in Scenario A is to be trusted. It is widely recognised that road safety and liability are key factors, and that automated cars will have to be much safer than regular ones; still, users may not accept or even reject road automation. The acceptance level can be different amongst social groups according to cultural, age and generational differences, and that user acceptance is closely linked to political goals from both local and national authorities.

User and societal acceptance are related to the consensus of solutions of ethical problems around automation. An ethical framework and discussions involving the public are needed.

Considering that connectivity is a key enabler of advanced vehicle automation, data is a key enabler of CAD. CAD requires vast amounts of data to be gathered and processed for the benefit of all. While the need to ensure access to data is paramount for ensuring the full deployment of CAD, the protection of personal data is essential, as well as cybersecurity. Users are willing to embrace CAD, provided that they know which of their data is being shared and that they are given the choice with whom they share data. More research is needed on AV black boxes and who will have access to the data. In particular regarding Scenario A, the legislative framework needs to set solid safeguards.

3.2. Scenario B: Authority driven with focus on collective transport

Many developments, bottlenecks and enablers that were described in Scenario A also hold for Scenario B. The difference is that in this scenario shared mobility in the form of public transport is far more on the foreground, and automated last mile solutions, to connect people to longer distance trains and busses, are envisaged. This means that these last mile solutions (like pods or shuttles) need to be fully automated, if they are going to replace privately owned vehicles on a large scale, and if they are going to be accessible to a large variety of users, also without a driver's licence and not capable of driving the vehicles themselves.

The emphasis on developments driven by policies also means that cities have the possibility to widely ban private cars from their roads, discouraging the use of non-shared automated vehicles with various measures, changing the way in which cities are structured quite significantly, and freeing up space for public transport, automated shuttles and walking and cycling.

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3.2.1. Bottlenecks and challenges

Policy and regulatory needs

Evidence of effects of new technologies is often difficult to obtain. Results from lab-tests or limited-scale field tests are not always sufficient to base a policy on, let alone regulations – even if the data shows an overall positive impact. This calls for sound research designs and thorough evaluation methodologies.

As for Scenario A, the demand for reliable and robust technology will increase. Again, this raises the question regarding the responsibility of technology and liability of technology companies in making the automated system more autonomous. Regulation has to address this progressive transfer of responsibility.

Shared, automated mobility will need to produce and collect data, making the issue of data protection important. More comprehensive regulation and strict enforcement of existing regulation is needed to protect personal data.

Regulations concerning automated public transportation is paramount – especially regulations connecting private service operators, road operators and public authorities. Distribution of roles between and rules of vehicle technologies, road technologies and communication technologies must come from successful experiments and implemented in such a way that responsibility of each party is clear in case of failure, defect, incident or crash. This calls for a clear verification/validation process of safety before allowing the public to use CAVs (see also Deliverable 3.1, chapter 3, Deployment).

The aforementioned possibility for cities to ban private cars from their roads, because their role can be taken over by public CAVs, may be true in a functional sense at some point but would probably meet public opposition. Private car use is widely associated with freedom, personal image and privacy. A challenge is to address these aspects and offer other important values like comfort and affordability.

Finally, regulation must also consider how and by whom the whole automated public mobility is controlled. As for air traffic or guided ground transportation, there is a high probability that a supervision by controllers will be needed. This new activity must be clearly regulated.

Socio-economic assessment and sustainability

Last-mile research projects in the next few years should clarify the potential of this scenario and what challenges remain to be solved. For example, experiments with operational models such as on-demand door-to-door service in high-density areas and fixed route/time service in less dense areas to balance fleet costs would bring required insights. Currently, automated pods and shuttles are tested mainly in heavily populated areas: shopping centres, amusement parks, airports, campus areas, etc. This leads to think that one enabler for Scenario B may be metropolitan designs, where private car use is restricted. In such areas, special routes and infrastructure can be constructed for automated collective transport vehicles. In those cases, these vehicles extend well-working mass transit.

To reach feasibility in less-populated areas, automated collective transport should become affordable for the less densely populated areas finding a good balance between the overall costs and level of service. In these areas, automated collective transport would no replace or

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improve existing services, as they do not exist. Consequently, they would bring additional public transport services at a high cost (due to the technology and infrastructure requirements). Financing those deployment will be an additional challenge in scenario B. Naturally, to reach the non-urban areas, the vehicles need to be able to traverse various small road types with higher speed than driven by the current automated shuttle buses.

Comparing Scenario A, where automated vehicles would be owned by private companies, to Scenario B, building specific infrastructure for automation would be more straightforward, since it would be constructed to enable public transport lines.

Achieving social equity in terms of mobility should be easier, if the overall transport system and pricing can be planned centrally. On the other hand, innovation coming from start-ups and other private sector players may be harder to incorporate if dialogue between them and the public authorities is non-existing or vague. Therefore, there is a risk that the development of mobility services based on authority driven collective transport is slow if the dialogue with innovators of this domain as well as innovative procurement of services are not ensured to keep up with the pace of development.

Still, a high level of standardisation would be expected and well-working pilot sites, before the public sector would consider making substantial investments in automated vehicle solutions for their collective transport.

Safety validation and roadworthiness testing

In general, challenges identified for Scenario B are the same that those identified for Scenario A. An advantage of Scenario B is that the area of operation is well known (e.g. bus/tram lines). Moreover, the following conditions are in favour of successful assessment of safety risks during development, validation and execution:

- ODD well defined, can be limited if needed
- Meteorological conditions known over years
- Single traffic/driving
- "Local rules" of traffic code known
- Homogenous driver behaviour.

Public transport is targeting directly SAE L4 for very limited applications (e.g. autonomous shuttles). As a result of above-mentioned conditions and the knowledge of the area, scenario-based, route-based and infrastructure-based approaches to validate CAD are key for safety assessment of public transport.

Currently, the testing and validation approach is based on scenarios and accident analysis and weather conditions. Data are collected also from connected infrastructure, creating statistics that help building scenarios. Critical scenarios can be tested on a test track and in simulation environment. The basic rule is that the same test is repeated more than once, generally 10–20 times.

Taking into account that Scenario B focuses on collective transport and it is driven by authorities, there is a need for involvement of public authorities in the testing and validation process. This is to create an understanding of the hidden problems behind the deployment of CAVs in collective transport in different regions and areas of operation.

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User awareness, societal acceptance and ethics, driver training

In Scenario B, shared and automated mobility is part of the integrated planning process and the road authorities play an important structuring and coordinating role. Part of this role is to guarantee that services offer minimum safeguards for passenger safety and pedestrian safety.

Also, in Scenario B, public awareness is a key challenge to acceptance. Road authorities work together with different stakeholders to offer hands-on experience and informed public discussion. An increase in collective transport will mean that users accept a shared solution and the willingness to give up autonomy and private cars. Therefore, equity and accessibility to collective services should be addressed.

3.2.2. Enablers to speed up processes

Policy and regulatory needs

A comprehensive regulatory framework for CAD across the whole of Europe is an ambitious goal. Developing and agreeing harmonised regulation for a selection of the road network, the Trans-European Transport Network (TEN-T) roads, could be an interesting enabler for CAD – at least on the main roads that link the various parts of Europe together. It would fit in well with the TEN-T policy to eliminate technical barriers and adopt innovative digital technologies. Allowing (the self-driving mode of) vehicles on specific parts of the road network is in line with the concept of ODD, which details for which circumstances a self-driving technology is built to function. The harmonised regulation could be extended towards standardised road layout that would make interpretation of the traffic situation easier for automated vehicles.

As for technical regulations, enablers are similar to those presented for Scenario A. UNECE Working Party 29 seems appropriate to ensure "technical regulatory policy harmonisation". Focus on public transportation and specific corresponding vehicles should however be prioritised compared to Scenario A. In case of Scenario B, personal cars may be less automated than public transportation vehicles.

As for shared mobility and existence of automated public transport services, best practices deriving from current or future piloting or testing should again pave the way for sustainable use cases. In this respect, experiments on automated public transportation rather than use of private cars should be highly encouraged. For example, a national project on CAD in France, i.e. SAM (Sécurité et Acceptabilité de la Mobilité et de la conduite autonomes) is focusing on 11 public transportation use cases out of a total of 13 (only two on private cars). More exactly, out of the 11 experiments, 2 combine a mix of public transport service (shuttles operated by PTO), and shared but potentially privately operated taxis (robotaxis). Experiments are key in identifying the relevant regulations concerning the offer, use, organisation and safety of public transport.

As for responsibility, current activities in different countries (e.g. France, Germany, UK, etc.) on traffic code and civil and criminal laws applied to personal cars should provide some insights into how to apply what is planned for cars to public transport. Work is on-going in some countries and again should be encouraged and supported.

Finally, the application of the General Data Protection Regulation (GDPR) across Europe since May 2018 has produced and will still continue to produce good results related to the protection of data collected and treated in the case of automated public transportation.

Academic publications and conferences are starting (and will continue) to produce initial feedback that will facilitate application and adjustments of data protection regulations and practices in the future.

Socio-economic assessment and sustainability

During the last ten years, there have been numerous automated shuttle bus demonstrations across Europe. However, the number of systems in operation are few. Most demonstrations have been operated at slow speeds (below 20 km/h) to ensure safety. Higher speeds require safe areas with good visibility, or installations in infrastructure, mainly for detecting and preventing pedestrians and cyclists from accidents with automated vehicles (see also Deliverable 3.4, chapter 3, Physical and Digital infrastructure).

At slow demonstration speeds, such people movers often have difficulties to compete against other modes of transport in terms of travel time. To assess the true potential and best use cases of automated collective transport, more operational tests would be needed with appropriate focus also in the infrastructure and driving speeds, capacity of the service, need of human operator and costs.

Scenario B foresees automated vehicles in wide last-mile use, operated as part of public transport. Such tests are becoming technically possible, but they will require deep integration with public transport e.g. to match pod fleet movement with public transport timings and to be able to plan and pay full trips easily, e.g. with a mobile app. Transfer times from buses/trams/trains to the last-mile service must be short and capacity sufficient to attract passengers. There is also a need for research and experiments on curb-space management techniques and transition area design or pricing.

Large public investments in this new, still relatively untested last-mile technology remains a topic. Current demonstrations take place mainly near airports and large shopping centres. Instead of gathering last-mile experiences, current demonstrations are about moving in densely populated no-car zones. Extending public transport areas with automated vehicles requires further investigations. Specific attention should be paid towards the possibility that automated transport could lead to a decline in walking and cycling.

Safety validation and roadworthiness testing

For Scenario B, industry players and authorities need a new way of testing, certifying and monitoring the deployment of CAV for collective transport. CAVs will only help to meet public policy goals if they come as shared fleets integrated with public transport. Even though Scenario B requires new testing standards, protocols and methodologies, the following enablers discussed in this section will speed up the process of its deployment (see also Deliverable 3.1, chapter 3, Deployment).

AVs are an opportunity for city transport as public transport offers the quickest development path to full autonomy because it can start operating in a limited area (ODD). Practical cases reflecting a diversity of use cases and territories are important to truly understand the hidden problems and specific concerns in certain public transport applications. Public transport path for full autonomy, or full autonomy on certain routes, should be underpinned by business models for urban mobility service providers that include interests and needs of all players. A provision of ‘Mobility as a Service’ platforms (to control travel behaviour) would encourage shared mobility and limit private car use.

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Sharing scenarios and best practices can significantly reduce costs at technical and organisational level. For that reason, a strong collaboration is needed between authorities internationally (associations, policy decision makers on mobility, road safety, urban planning, traffic control, etc.) as a natural way to exchange information. The responsibilities of public transport authorities for all urban mobility services / mobility operators should be revised and re-defined. Moreover, a policy and regulatory framework should oblige manufacturers and operators to share experiences and key data to ensure a smooth learning process.

Additional enablers come in the form of working groups, associations and organisations; and the development of new standards with international support and resources will speed up the deployment process of AV in public transport. Successful validation of Scenario B can take place, if it is aligned with an approval framework (UNECE/EU/national level). Moreover, networks like POLIS (https://www.polisnetwork.eu), The CIVITAS Forum Network (https://civitas.eu), or international events such as the Conference on the Impact of Autonomous Vehicles on Public Transport could streamline the process.

The involvement of end-users is a crucial step forward. Trials should also begin on public roads to see how best to integrate CAVs into the mobility eco-system. It is important to test public acceptance (behavioural studies mainly on HMIs interpretability and "etiquette" of the vehicle on the roads), the integration of autonomous shuttles in pedestrian zones, offering additional services where no public transport services existed before as well as social inclusion translate into more mobility options for all (elderly people, disadvantaged communities, children).

At the same time, Field Operational Tests (FOTs) are needed to obtain relevant, real world data that supports the improvement of physical/virtual validation tools and methodologies and the use of shared CAVs on public roads. It is important to understand the risks that could impact safety critical functionalities due to cyber-attacks and failure (functional safety) but also potential inadequate control, undesirable control actions, driver misuse and inadequate interaction with other road users (operational safety).

User awareness, societal acceptance and ethics, driver training

Road authorities should work together to contribute to further recognition that transport services are safe and that liability safeguards are well established. Efforts should address different social groups according to culture, age and generational differences, and link user acceptance to political goals from both local and national authorities.

The legislative framework sets solid safeguards regarding the access to data and data protection. Cybersecurity is safeguarded through the proactivity of public authorities and the strategic control of road authorities. Users embrace CAD and shared mobility as they know which of their data is being shared and that they are given the choice with whom they share data.

Public authorities ensure that users are thoroughly informed about when and how to use automation features and benefit from adapted education and training to understand the basics of the technology. However, with a shift to SAE L2, L3 and above driving functions and training will need to be clearly defined. As a result, non-expert users using these services should be empowered to contribute in public decision-making process. Therefore, transition is gradual and made simple for a non-expert user.

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Users should be trained to know how to operate different types of vehicles working on different systems and how to drive in different modes of automation, with the support of car rental companies and car manufacturers. Professional drivers should be given a different role and tasks which could include remote controlling and dedicate more time to administrative tasks.

3.3.Relations to ongoing activities outside of ARCADE

EU Projects

The table below is composed of relevant EU R&I projects that are related to societal aspects of CAD. Efforts are currently taking place at EU level to address different aspects of CAD ranging from user acceptance, standards, piloting and truck platooning.

Project Name	Duration	Website
AdaptIVe	January 2014 – June 2017	http://www.adaptive-ip.eu/
ADAS & me	September 2016 – February 2020	http://www.adasandme.com/
AUTOPILOT	January 2017 – December 2019	https://autopilot-project.eu/
BRAVE	June 2018 – May 2020	http://www.brave-project.eu/
Collective Innovation for Public Transport in European Cities (CIPTEC)	May 2015 - April 2018	http://ciptec.eu/
CLOUD SLVA	October 2017 – June 2020	https://cloud-lsva.eu/
CONCORDA	October 2017 – June 2020	https://connectedautomateddriving.eu/project/concorda/
ENABLE-S3	May 2016 – May 2019	https://www.enable-s3.eu/
ENSEMBLE	June 2018 – May 2021	https://platooningensemble.eu/
ESCAPE	October 2016 – November 2019	http://www.gnss-escape.eu/
ESPLANADE	January 2017 – December 2019	https://esplanade-project.se/
European Bus System of the Future 2	May 2015 – April 2018	https://ebsf2.eu/
FOT-NET	January 2011 - April 2014	https://fot-net.eu/
GALILEO 4 MOBILITY	-	http://www.galileo4mobility.eu/
HoliSec	November 2017 – April 2020	https://www.vinnova.se/en/
ICT4CART	September 2018 – August 2021	https://www.ict4cart.eu/

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INFRAMIX	June 2017 – May 2020	https://www.inframix.eu/
InterACT	May 2017 – April 2020	https://www.interact-roadautomation.eu/
LEVITATE	December 2018 – November 2021	https://levitate-project.eu/
L3Pilot	September 2017 –August 2021	https://www.l3pilot.eu/
MOOVE	2015 - 2019	-
MuCCA	August 2017 – January 2020	https://mucca-project.co.uk/
PEGASUS	January 2016 – May 2019	https://www.pegasusprojekt.de/en/home
PRYSTINE	May 2018 – June 2021	https://prystine.eu/
ProPART	January 2018 – December 2020	http://propart-project.eu/about/
SaferTec	January 2017- December 2019	https://www.safertec-project.eu/
SAKURA	August 2018 – March 2021	-
SCOUT	July 2016 – June 2018	https://cordis.europa.eu/project/rcn/204978/factsheet/en
SkillFull	October 2016 – September 2019	http://skillfulproject.eu/
TrustVehicle	June 2017 – May 2020	http://www.trustvehicle.eu/
VI-DAS	September 2016 – August 2019	http://www.vi-das.eu/

Ongoing initiatives

There are various ongoing initiatives taking place at EU and international level on CAD. The purpose of the section below is to give an overview of the relevant activities by explaining their function and role.

EU–US–Japan trilateral Working Group on Automation in Road Transportation

At an international level, the EU–US–Japan trilateral Working Group on Automation in Road Transportation is a reference group with representatives of the European Commission, the United States Department of Transport, and the Japanese Ministry of Land, Infrastructure, Transport and Tourism.

The ARCADE project provides an EU expert group for the trilateral activities. In the framework of the trilateral cooperation, the Sub-working group Safety Validation and Roadworthiness Testing was created with the objective of addressing common challenges for testing and assessment of automated vehicles in the different regions. The Sub-working group for Impact Assessment has been created with the objective to coordinate the impact assessments performed in the field of CAD.

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C-ITS Platform

The European Commission decided in early 2014 to take a more prominent role in the deployment of CAD, by setting up a C-ITS Deployment Platform. The Platform is conceived as a cooperative framework including national authorities, C-ITS stakeholders and the Commission, in view to develop a shared vision on the interoperable deployment of C-ITS in the EU. Hence, it is expected to provide policy recommendations for the development of a roadmap and a deployment strategy for C-ITS in the EU and identify potential solutions to some critical cross-cutting issues.

In the frame of supporting the deployment of C-ITS on European roads, there are a number of C-ITS real-life pilot projects funded under TEN-T and CEF which will create new ITS services for all European road users. These projects will test vehicle-to-infrastructure and vehicle-to-vehicle interactions by using both short-range and cellular communications.

Single Platform for Cooperative, Connected, Automated and Autonomous Mobility (CCAM)

The European Commission has set up an informal group of experts, the Single Platform for open road testing and pre-deployment of Cooperative, Connected, Automated and Autonomous Mobility (CCAM).

The group provides advice and support to the Commission in the field of testing and pre-deployment activities for CCAM. The group is made up of 100 experts, appointed for a period of three years.

European Road Transport Research Advisory Council (ERTRAC*)*

In 2014, ERTRAC launched a Task Force on “Connectivity and Automated Driving”: over 80 experts from industry, research institutes and public authorities gathered to work on a common European vision of automation of road transport. The objective was to gather private and public stakeholders in order to support a harmonised approach for implementing higher levels of Automated Driving in Europe.

The ERTRAC Strategic Research Agenda is being implemented through research roadmaps, which presents topics for research, development, and the deployment of innovation. Together, the ERTRAC roadmaps cover all aspects of the transport system and allow to reach the objectives set in the Strategic Research Agenda.

The key challenge “Safety Validation and Roadworthiness testing” is addressed in the Safe Road Transport Roadmap and strongly connected to several other ERTRAC Roadmaps, especially the roadmaps on Connected and Automated Driving and Urban Mobility.

Joint Research Centre (JRC)

The Joint Research Centre (JRC) is the European Commission's science and knowledge service.

The new report by the Joint Research Centre (JRC) titled “The future of road transport - Implications of automated, connected, low-carbon and shared mobility” identifies and analyses the enablers for the transformation of road transport, such as data governance, infrastructure, communication technologies and cybersecurity, and legislation.

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Consumer test programmes

Consumer test programmes put in practice test and assessment protocols to provide information to the consumer about vehicle safety. The New European Car Assessment Programme (Euro NCAP) created the five-star safety rating system to help the consumers to compare vehicles and to identify the safest choice among the vehicles in the market.

Although Euro NCAP test and assessment protocols do not capture the complexity of the real world, they promote vehicle improvements and the integration of technologies that improve safety and deliver a true benefit to consumers in Europe and to society as a whole.

Euro NCAP current focus is on driver assist systems. In the context of CAD, these are SAE L2 systems according to SAE standards.

Currently, systems that would allow drivers to take their hands off the wheel for extended periods of time or to perform secondary tasks are not allowed on our roads. The Euro NCAP Automated Driving Working Group is formed by experts that are currently discussing how to create a methodology able to test and assess AD functions of higher level of automation.

As for the use of different test methodologies (track, simulations, FOTs) no decisions have been made. The Virtual Validation Working Group has also been created in order to discuss further concerning this topic. This group had its first meeting in July 2019.

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3.4. Actions to be taken

Actions have been identified in all thematic areas, with the relevant stakeholders and the level of priority. The actions have been derived for all 4 scenarios. In the below table, priority actions are summarized with the prime actor involved.

3.4.1. Key actions, Prime actors and Priorities

Key Action	Prime actor	Priority
Perform societal needs and positive risk analysis from user and society perspectives	EU, Research	High
Development of commonly available (validated) AV simulation and other evaluation tools	EU, Research, Operators, authorities, OEM	High
Promote common methodologies and guidelines: FESTA Handbook, Trilateral impact assessment framework, ethics guidelines for trustworthy AI by the High-Level Expert Group on AI	Research, EU	High
Ethics evaluation based on technology understanding	EU	High
Study the impact on driver/users and operator training	Research, Operators, authorities, OEM	High
Secure privacy for mobility users	EU, Authorities	High
Organise both large-scale pilots (low level TRL) and FOTs (high level TRL) to assess the impact of the new technology and related services in different environments	EU	High
Development of EU-level databases to allow more reliable scaling up (data on accidents, mileage, etc. including ODD aspects, with sufficient details and granularity)	EU, Authorities, OEM	High
Alignment of vehicle regulation (and type approval) and corresponding assessment tools & procedures	EU, Authorities, OEM	High
Study the implications of land use policies on impacts of CAD	Research, urban authorities	Medium
Determine proper combination of virtual testing, closed test track and open road testing of AVs.	EU, Research, urban authorities, OEM	High
Develop new evaluation methods for the indirect long-term impacts of CAD	Research	Medium
Share and harmonise driving/traffic scenarios and best practices	EU, Research, urban authorities, OEM	High
Study expected life-time costs of CAVs and related infrastructure up keeping	Road authorities, research	Medium
Consensus building with respect to validation of methodologies, including Data-labelling standards	EU, Research, urban authorities, OEM	High
Develop procedures to manage validation of vehicle updates during the whole vehicle lifetime	EU, OEM, Authorities	High
Flexible AD regulation, enabling different solutions, within the boundaries of safety	EU, OEM, Authorities	High
Learn from adaptation of regulation, work towards common approach	EU, OEM, Authorities	High
Build common CAD framework	EU, OEM, Authorities	High
Make cross-border testing easy	EU, OEM, Authorities	High
Allow a successful transition of responsibility from the user to the automated system (robot, manufacturer, supplier, etc.).	EU	High

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Develop regulation regarding collection, use, re-use, of data and compliance to GDPR	EU	High
Develop models on co-habitation of private shared and public mobility	EU	High
Focus technical regulation on public transportation rather than private passenger cars	EU	High
Allow a successful transition of responsibility from user to the system (robot, manufacturer, supplier, etc.)	EU	High
Allow a successful transition of responsibility from the user to the automated system (robot, manufacturer, supplier, etc.).	EU	High
Research on long-term indirect impacts of automation, equity etc.)	EU, Authorities	High
Roles and liabilities over automated mobility should be clarified and consolidated	Research, road authorities	High
Develop a common EU testing and validation methodology	EU, research	High
Investigate how the role of operators and professional drivers will change with higher levels of vehicle automation	Research	High

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4. Conclusion and recommendations

Looking at research and innovation, technologies will come to the market as soon as they are mature enough to fulfil customer needs and will be applied to vehicles connected to the cloud and used. That is why the consequences of the scenarios do not differ strongly in D3.1 (Technologies & Vehicles), but with growing understanding of the capabilities of vehicles with such technology systems will be able to be defined clearer and clearer and new services will lead to new businesses around them and for the sake of their providers. This leads to slight differentiation of the scenarios in D3.4 (Systems & Services), without leading to different actions. Depending on how these systems and services are controlled and rolled out, there is clear differentiation for the individual user and his or her needs of comfort and time efficiency as well as for the society and its needs for safety and environmental efficiency in D3.7 (Society).

The priorities and actions resulting cover both specific and generic needs (see section 0). The recommendation to align stakeholders on common methodologies, vocabulary, data format, use case descriptions, and architectures is common to all areas, as well as the need for large-scale testing. The link with existing initiatives and EU projects has been made. It is also recommended to foster the integration of national projects and that the consolidation of results should be made through the knowledge base (WP4).

This is the result of the joint work in WP3 through the succession of sprints and workshops organized during the first year and consolidated during the September 1-3 2019 workshop. The results have been integrated in the ARCADE consolidated roadmap 2019 (D2.1).

This document will be updated annually and enriched with the results of ARCADE year 2 and 3 research. It delivers the analysis of the main challenges, enablers and actions required within different scenarios investigated during the year 1 of ARCADE.

Addressing the challenges highlighted by the society-related thematic areas will have a considerable impact on the deployment of CAD. EU regulation will increasingly need to be adapted to take into account technological advances. It is the responsibility of EU (and national) R&I projects to gather evaluation data that can be used for decision making at policy level along various impact areas that include financial and operational ones. EU Member States should share best practices and learn from those that already updated their regulation. This will lead towards the establishment of a common framework.

To enable learning from the early phase prototype systems and services all the way to mature ones, a sequence of studies from technical pilots towards more and more extensive field tests with real users of all kind and in different environments are needed. The knowledge that can be gained through them on technical readiness of the technology, implications on different user types and on societal impacts and mechanisms behind them would enable decision making that supports the development of the transport system toward sustainable solutions.

To ensure validity of results, development work is still needed on research methods, especially on indirect long-term impacts of CAD. The use of common frameworks that enable harmonization of certain aspects like KPIs in different studies would support easy comparison and overlook over several evaluation activities.

From a safety validation and roadworthiness testing perspective, ensuring functional and operational safety will play a decisive role in convincing users that CAVs are safe. For

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validation, transitioning should take place from one-time type approval to continuous monitoring of the vehicle operation (e.g. software updates). Putting in place measures against cyber-attacks is significantly important given the vast amount of data that the vehicle will produce. Furthermore, analysing the interaction and potential liabilities between the driver, automation and other road users should be included in the safety analysis. Actors such as road operators, OEMs, vehicle authorities and licence examiners should be involved.

Lastly, user awareness and acceptance are currently being investigated across Europe. Public opinion is diverse. Research projects should proactively inform users in order to gradually have CAVs featured more prominently on European roads. Privacy issues should be clarified and understood by users while at the same liability regimes should eliminate any legal uncertainty in case of an accident. In the coming years, an increasing number of CAVs on the road will be interacting with other vehicles and road users. For this reason, it will be challenging to identify the most suitable legal framework that ensures safety but at the same time fair compensation.

4.1.Recommendations

The recommendations for further actions are listed in **Error! Reference source not found. Error! Reference source not found.** and **Error! Reference source not found. Error! Reference source not found.**.

4.2. Next steps

The next steps, plan for ARCADE WP3 year 2, will focus on the following activities;

- Organise the thematic work for year 2 in 4 sprints, focussing on additional scenarios, approaches, impacts and proposed steps (T3.1)
- Perform 2 joint stakeholder networks workshops with WP2 to further consolidate, elaborate, develop and rank the key priorities as identified in the D2.1. This is planned for February and Spring 2020 (Task 2.3)
- Define additional scenarios, approaches, impacts and proposed steps for the thematic areas (T3.2, T3.3, T3.4)
- Provide thematic input for the EUCAD symposium at TRA in April 2020 in Helsinki and partially lead the sessions (WP3).
- Consolidate the year 2 input to the thematic areas and provide input to the knowledge base (WP4)

These steps will lead to three updated reports at the level of Society, Systems and Services and Technology and Vehicles (September 2020)

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Overview of ARCADE Deliverables Year 1:

Deliverable	Topic
D3.1	Technical thematic areas: challenges and scenarios
D3.4	Systems & Services thematic areas: challenges and scenarios
D3.7	Society thematic areas: challenges and scenarios

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6. Glossary: Acronyms and definitions

Term	Description
AD	Automated Driving
AI	Artificial Intelligence
ADAS	Advanced Driver Assistance Systems
ARCADE	EU H2020-DT-ART-2018-2019/H2020 CSA project, Aligning Research & Innovation for Connected and Automated Driving in Europe GA number 824251
ART	Automated Road Transport
CAD	Connected Automated Driving
CARTRE	EU H2020 ART06 CSA project Coordination of Automated Road Transport Deployment for Europe, GA number 724086
CAV	Connected Automated Vehicle
CCAM	The Cooperative, Connected, Automated and Autonomous Mobility Single Platform
D	Deliverable
EU	European Union
FOT	Field Operational Test
GDPR	General Data Protection Regulation
GRVA	Working Party on Automated/Autonomous and Connected Vehicles
H2020	Horizon2020, EU Framework Programme for Research and Innovation
HAV	Highly Automated Vehicles
HMI	Human-Machine Interface
NHTSA	National Highway Traffic Safety Administration (branch of the U.S. government, part of the Department of Transportation)
ODD	Operational Design Domain
OEM	Original Equipment Manufacturer
OTA	Over-the-air
PTI	Periodical Technical Inspection
SAE	Society of Automotive Engineers
SAM	French national CAD project «Sécurité et Acceptabilité de la Mobilité et de la conduite autonomes »
SOP	Start of Production
STRIA	Strategic Transport Research and Innovation Agenda
T	Task
TEN-T	Trans-European Transport Network
TRL	Technology readiness level
UNECE	United Nations Economic Commission for Europe
US	United States of America
VRU	Vulnerable Road User
WP	Work Package

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